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US Air Force Human Systems Integration (HSI) Maintenance (MX) Model Enhancements in the Improved Performance Research Integration Tool (IMPRINT)

Final Out Brief for 711th HPW/HPO

August 31st, 2009

Alion Science and Technology

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SCIENCE AND TECHNOLOGY

Agenda

- Project Background
- Simulation Software
- Simulation Development History
- Flightline Maintenance and Mission Generation Process
- Reliability and Maintainability
- Simulation Design
- Simulation Graphical User Interface
- Example Questions and Answers
- Potential Future Enhancements

Project Background

- Follow-on year of an original Advisory and Assistance Services (A&AS) contract.
- Investigating the relationship between human performance and Air Force (AF) operational metrics.
- In the previous fiscal year, developed a flightline maintenance and mission generation simulation of the F-15C Eagle.
- This year, the team added five weapon systems and additional capabilities.

Results prove the relevance of HSI by showing how integral the human is in total system performance.

Project Background co

- New weapon systems:
  - C-17 Globemaster III
  - CV-22 Osprey
  - F-15E Strike Eagle
  - MQ-1 Predator
  - MQ-9 Reaper

- New capabilities:
  - Graphical user interface for scenario definition
  - Dynamic charting for run-time metric evaluation
  - Incorporation of a *fatigue* stressor to impact performance
  - Improved custom comma separated value (.csv) reports

Simulation Software

- How does human performance impact operational metrics?
  - The Army Research Laboratory's (ARL) Improved Performance Research Integration Tool (IMPRINT) will facilitate this investi

- IMPRINT is
  - an HSI, Manpower, and Personnel Integration tool free for government use and available from ARL.
  - a dynamic, stochastic discrete event task-network modeling tool designed to help assess the interaction of Warfighter and system performance throughout the system lifecycle.

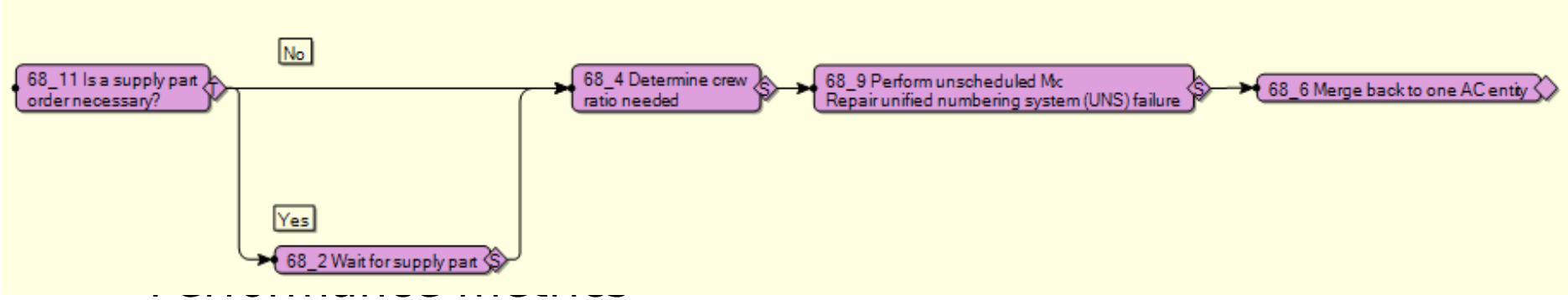
Simulation Software cont.

Inputs

- Task duration and accuracy
- Manpower
- Tactical decisions

Task-Network Human Performance Model

Input gathered from existing data, literature, and SMEs

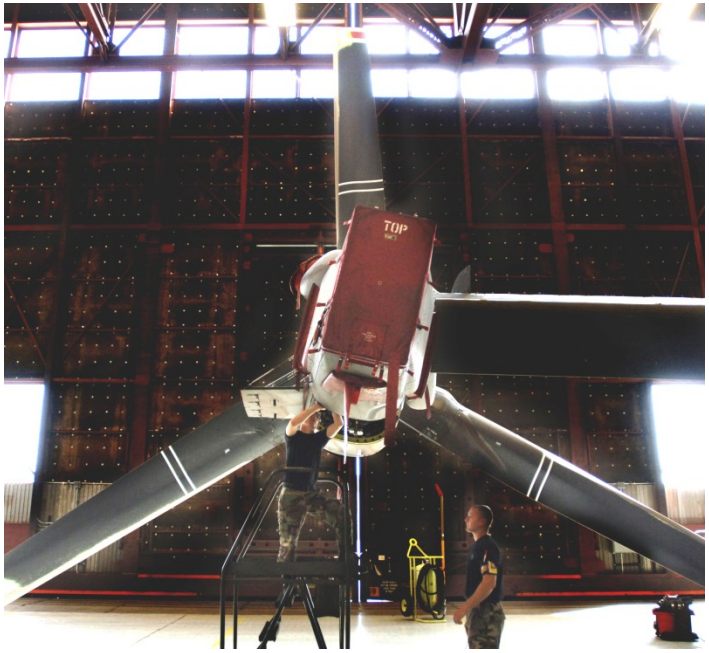


Simulation Development History

1. 711th selected five weapon systems capturing the AF's broad capabilities.
2. Conducted literature review of each weapon systems mission generation process.
   - Dash six technical manuals
3. Submitted HSI questionnaires to subject matter expert contacts at McGuire (C-17), Hurlburt Field (CV-22), Seymour Johnson (F-15E), and Creech (MQ-1/9).

Simulation Development History cont.

4. Visited Hurlburt Field to observe CV-22 Osprey production.



Nacelle Mx www.afsoc.af.mil

Corrective Mx Repair www.afsoc.af.mil

Simulation Development History cont.

5. Visited Creech AFB to observe MQ-1 Predator MX operations.

Ground Control Station

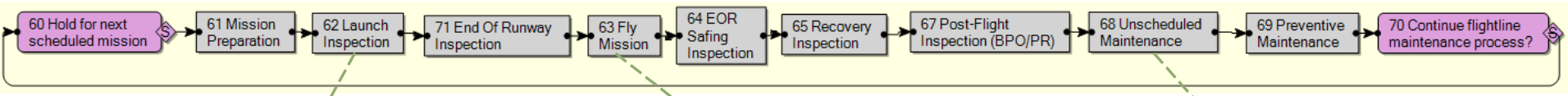
MQ-1 Predator

Simulation Development History cont.

6. Created software plug-in for IMPRINT Pro to implement the following simulation capability enhancements:
   - Graphical user interface for scenario definition
   - Dynamic charting for run-time metric evaluation
   - Incorporation of a *fatigue* stressor to impact performance
   - Improved custom comma separated value (.csv) reports

7. Added high-fidelity human performance modeling to the IMPRINT Pro simulation to capture the five new weapon systems.

Flightline Maintenance and Mission Generation Process



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- There is a consistent order to the business of flightline maintenance and mission generation.
  - Between missions a maintenance team performs preventive scheduled inspections and corrective unscheduled maintenance.

Reliability and Maintainability

- Reliability – How often does each aircraft component require a corrective repair (unscheduled maintenance event)?
  - Mean Flight Hours between Unscheduled Maintenance Events

- Maintainability – When a component needs a corrective repair how many maintainers does it require and how long does it take to repair?
  - Mean Event Crew Ratio
  - Mean Event Time

CV-22 Osprey AE1107C Engine

Notional Example

Reliability: 20 flight hour mean repair frequency

Maintainability: 4 hour mean repair event time (3 hour standard deviation)

Maintainability: 3 maintainer mean event repair team (2 maintainer standard

Simulation Design: Independent Variables (Input)

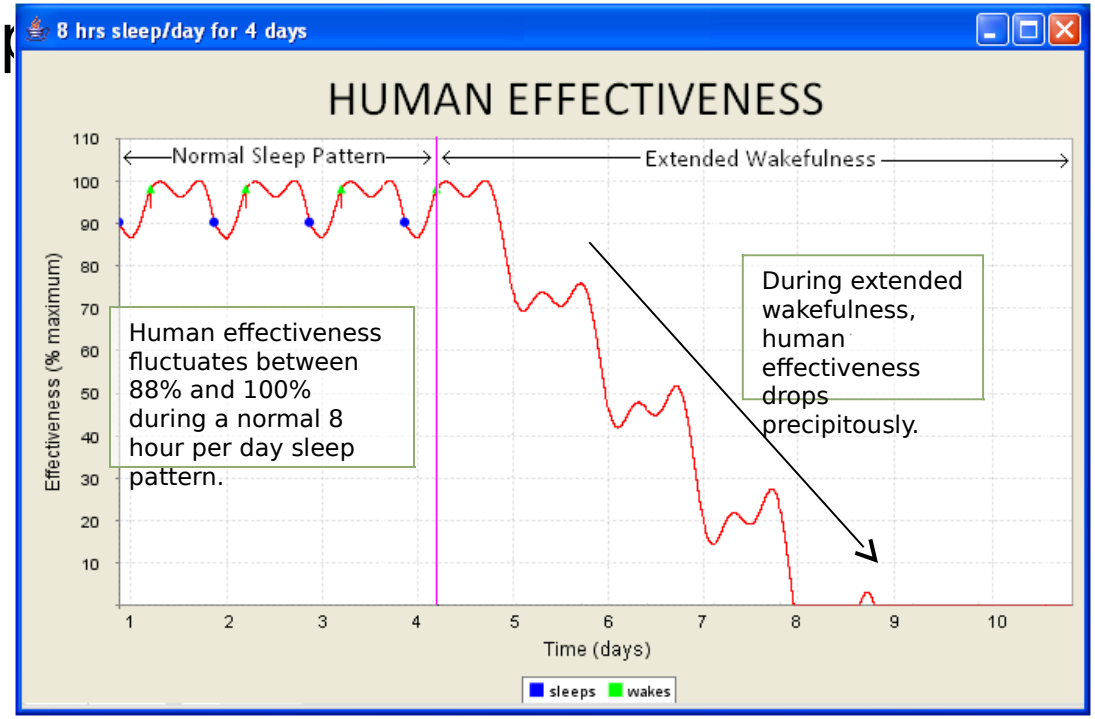
- Independent variables (specified before each model run):
  - Force
    - Number of weapon systems
    - Number of maintainers
    - Number of fueling trucks
  - Mission
    - Simulation duration
    - Scheduling (mission start times and flight times)
    - Abort and attrite probabilities
  - Maintenance
    - Mean Flight Hours between Unscheduled Maintenance Events (Reliability)
    - Mean Event Time (Maintainability)
    - Mean Event Crew Ratio (Maintainability)
    - Fatigue
  - Supply
    - Probability of ordering a supply part
    - Mean time to receive the supply part

Simulation Design: Operational Metrics (Output)

- Operational Metrics:
  - Sortie generation rate
    - The number of aircraft per day that complete a successful mission
  - Mission capable rate
    - The percentage of aircraft available to support a mission
  - Unscheduled maintenance man-hours
    - The number of man-hours spent correcting aircraft in the scenario
  - Scheduled maintenance man-hours
    - The number of man-hours spent performing scheduled maintenance
  - Administrative delay time
    - The total time aircraft have to wait until maintenance can be performed
  - Flying schedule effectiveness
    - The total delay time of all tardy mission launches
  - Environment, safety, and occupational health (ESOH) interactions
    - A tally of maintainer interactions with ESOH hazards

Simulation Design: Fatigue

- Dr. Steven Hursh's Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE) model predicated on:
  - Circadian rhythms, recovery and decay rates, and sleep



  - Human effectiveness after 8 hours of sleep per day for the past 4 days

Simulation Design: Simplifying Assumptions

- No major scheduled preventive maintenance
  - Programmed depot maintenance (PDM), hourly post flight (HPO), preventive (PR), home station check (HSC)
- No indirect/administrative work of crew chiefs, Mx specialists, or weapon specialists
  - Only flightline manual labor was considered
- No hot refueling
- No support equipment maintenance considered
- No aircraft battle damage repair (ABDR)
- All aircraft start as fully mission capable

Simulation Design: Schematic

Independent Variables

- Force
- Mission
- Maintenance
- Fatigue
- Supply

Independent variables describe the operational scenario

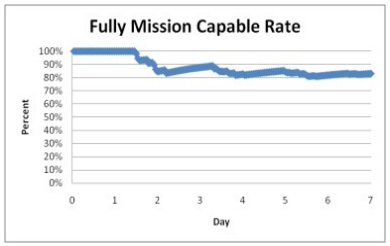
IMPRINT
Improved Performance Research Integration Tool

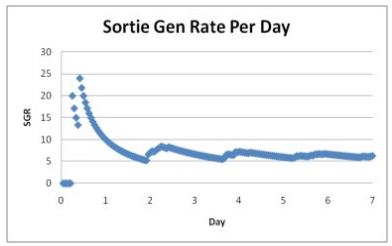
Operational Metrics

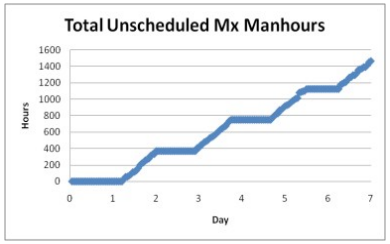
- Sortie generation rate
- Mission capability rate
- Unscheduled Mx man-hours
- Scheduled Mx man-hours
- Administrative delay time
- Flying schedule effectiveness
- ESOH Interactions

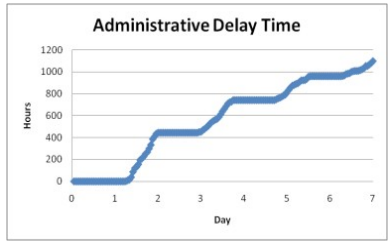
Operational metrics tell the story of how the scenario unfolded

Nellis AFB Flightline



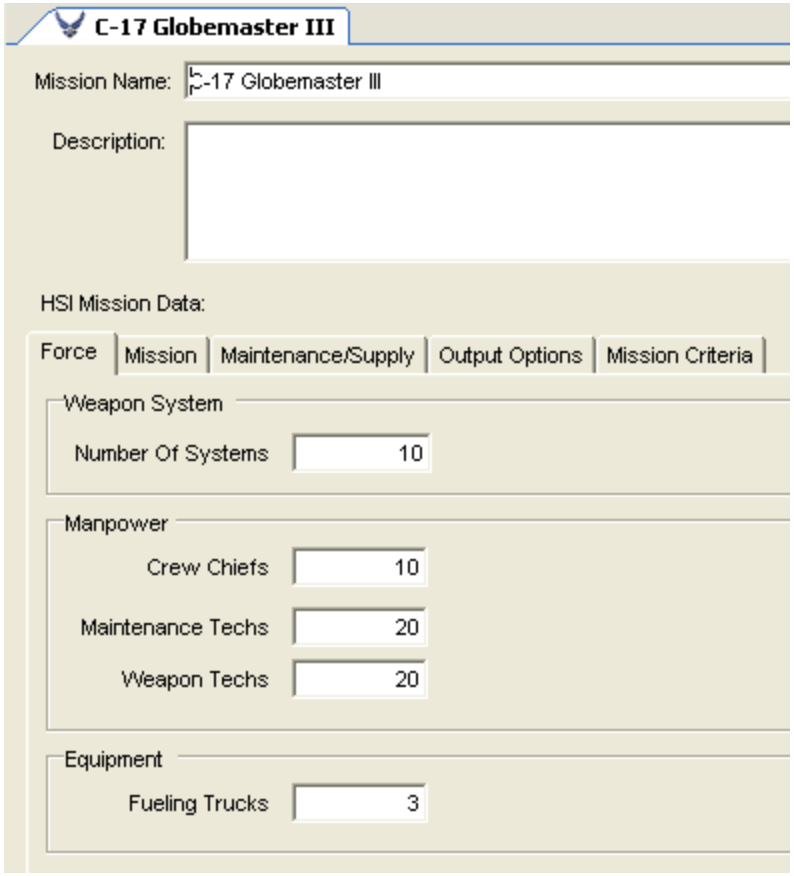






Simulation Graphical User Interface

FORCE



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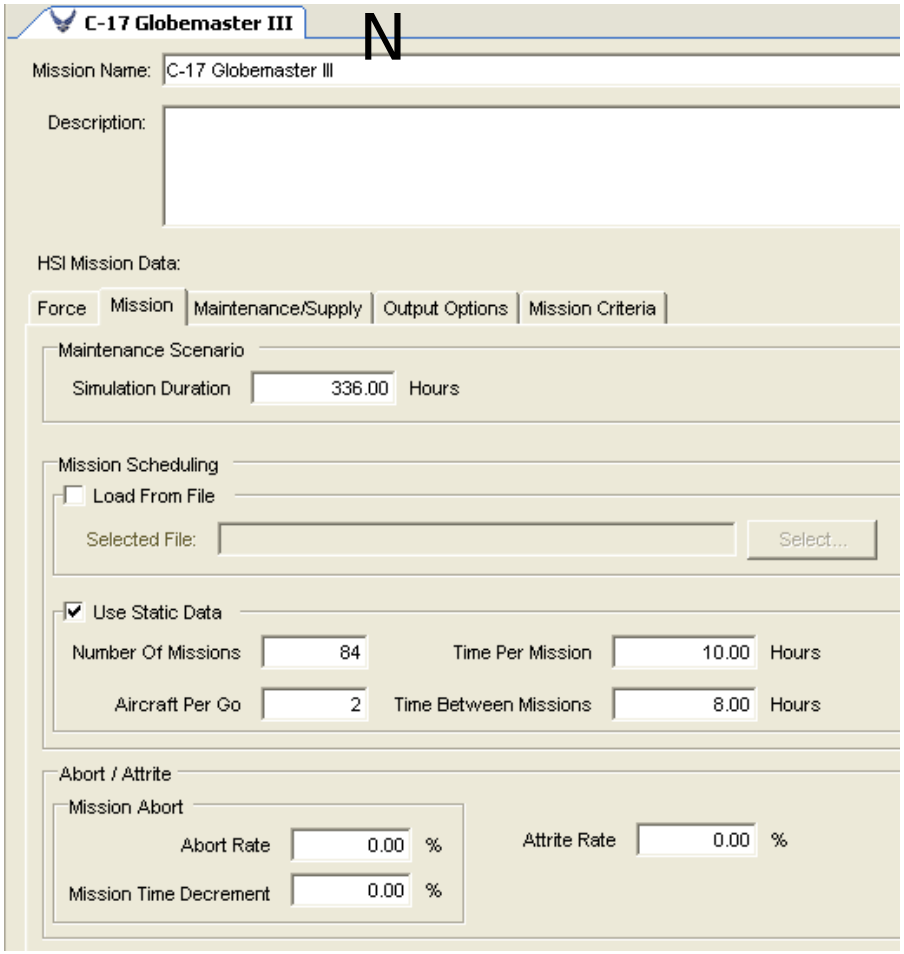
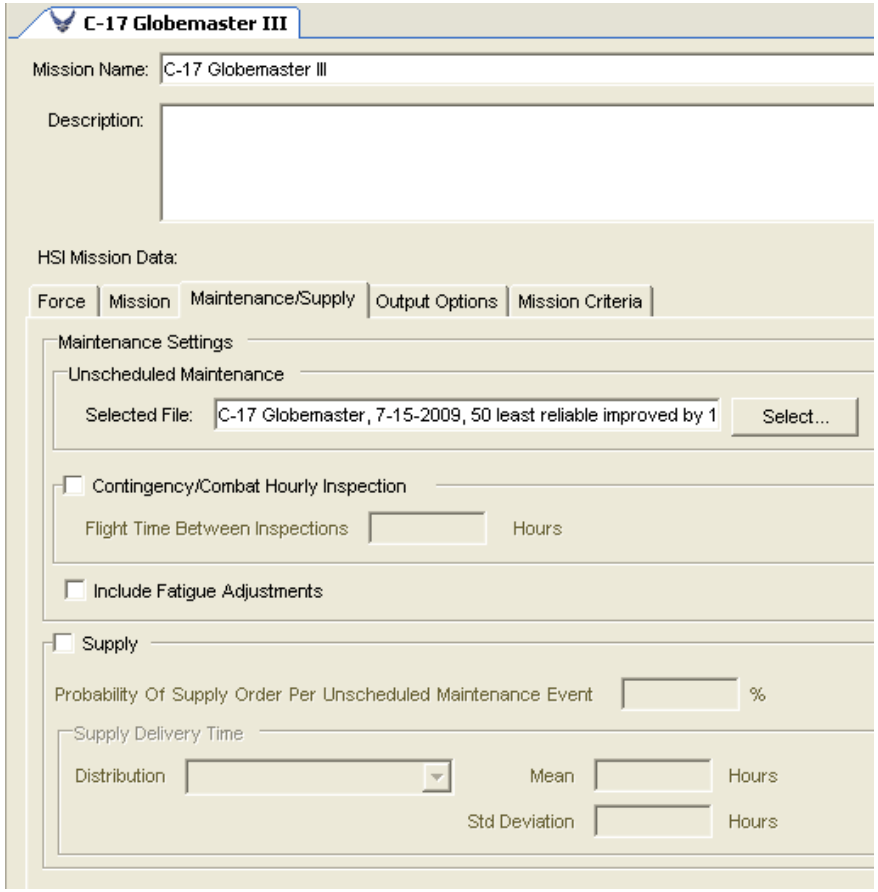
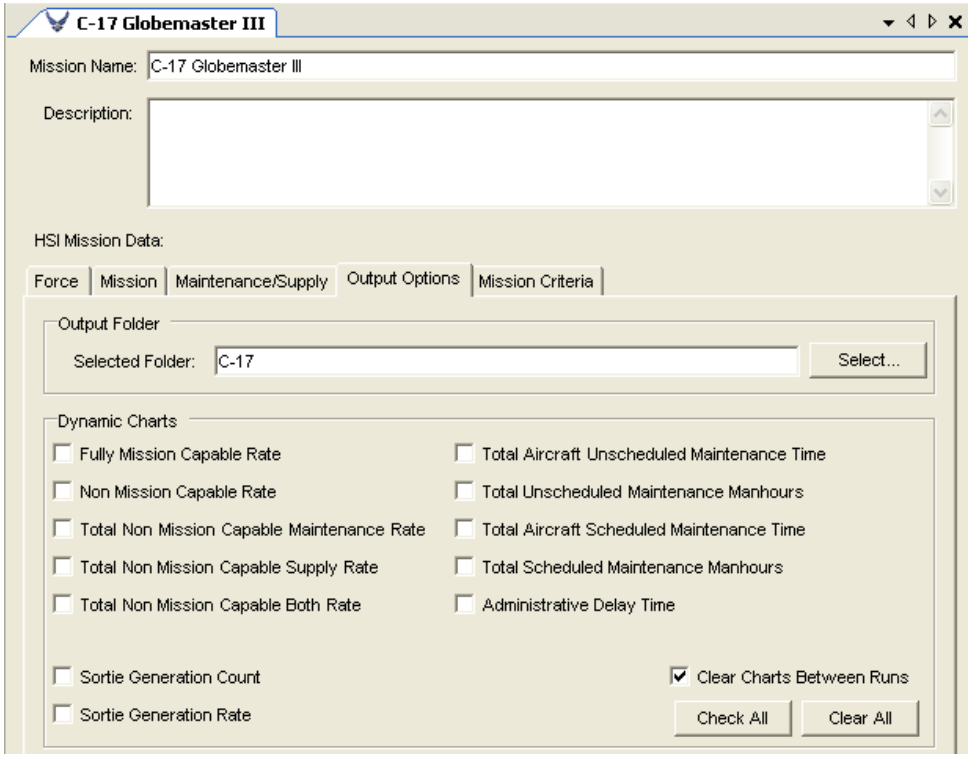


Simulation Graphical User Interface cont.

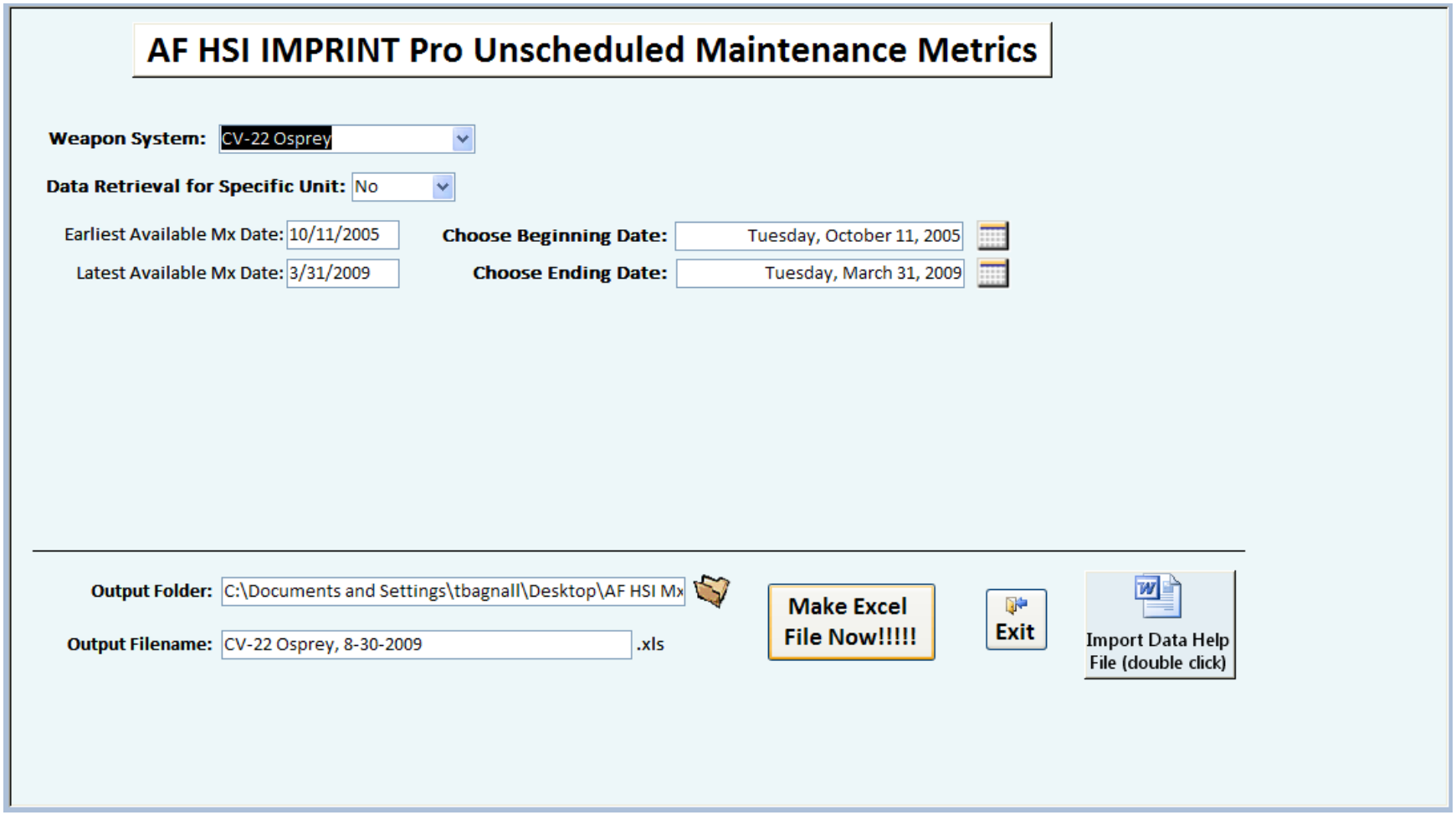
MAINTENANCE/SUPP



OUTPUT OPTIONS



Unscheduled Mx Data Creation Tool



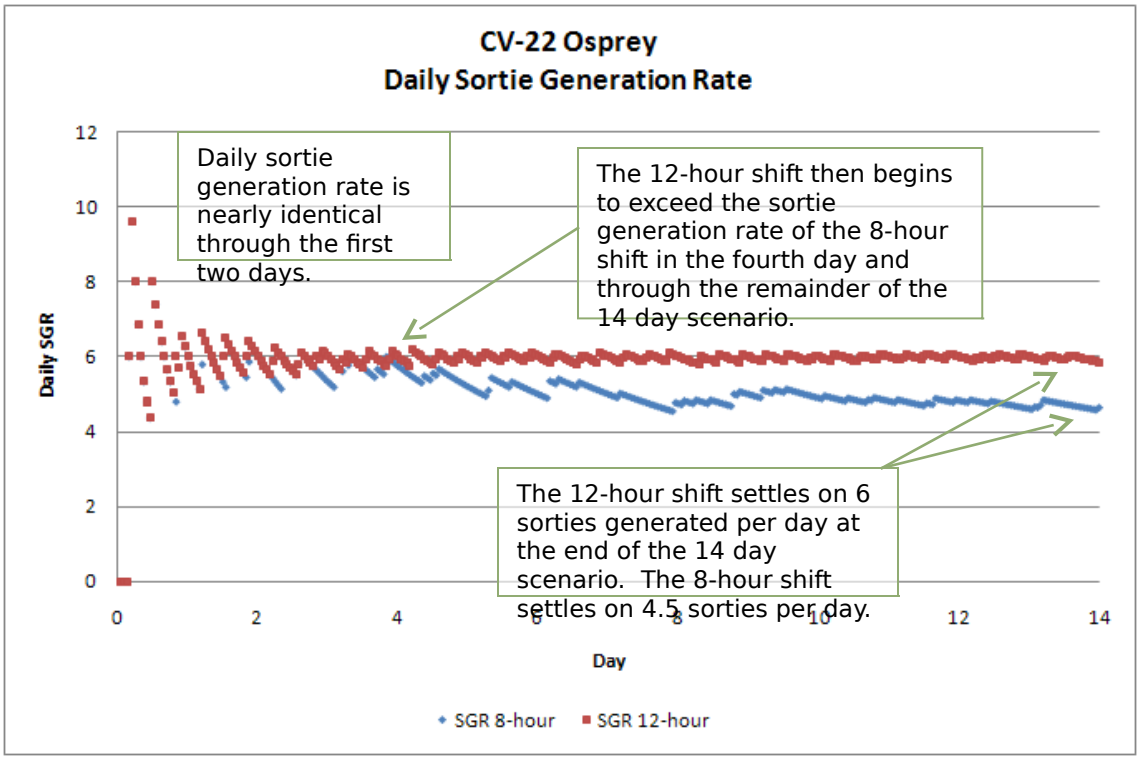
Unscheduled Mx Data Creation Tool cont.

Sample File

CV-22 Osprey, Unscheduled Mx Statistics, 10/11/2005 - 3/31/2009							
UNS	UNS Description	MTBME (hr)	MET (hr)	MET Std Dev (hr)	MECR	MECR Std Dev	Events
XYZ123	VIBRATION	126	1.416	2.441	1.824	0.833	500
XYZ124	SUPPRESSION	117	0.865	0.978	2.145	0.862	226
XYZ125	CONTROLLER	128	0.833	0.711	2.160	0.809	148
XYZ126	ACCELEROMETER	2,137	1.972	1.251	2.333	0.943	125
XYZ127	GENERATOR	256	1.230	1.690	2.360	1.229	119
XYZ128	NO. 2 COUNTER	1,603	1.792	1.556	1.500	0.500	117
XYZ129	FORCE CONTROL	916	0.926	0.174	2.143	0.639	116
XYZ130	SYSTEM	3,205	1.500	0.500	2.000	0.000	116
XYZ131	AVIONICS	916	0.333	0.327	1.429	0.495	116
XYZ132	AIR CONDITIONING	169	1.364	1.465	1.921	0.664	116
XYZ133	COMPRESSION	103	0.951	0.972	2.516	1.478	116

Example Question and Answer 1

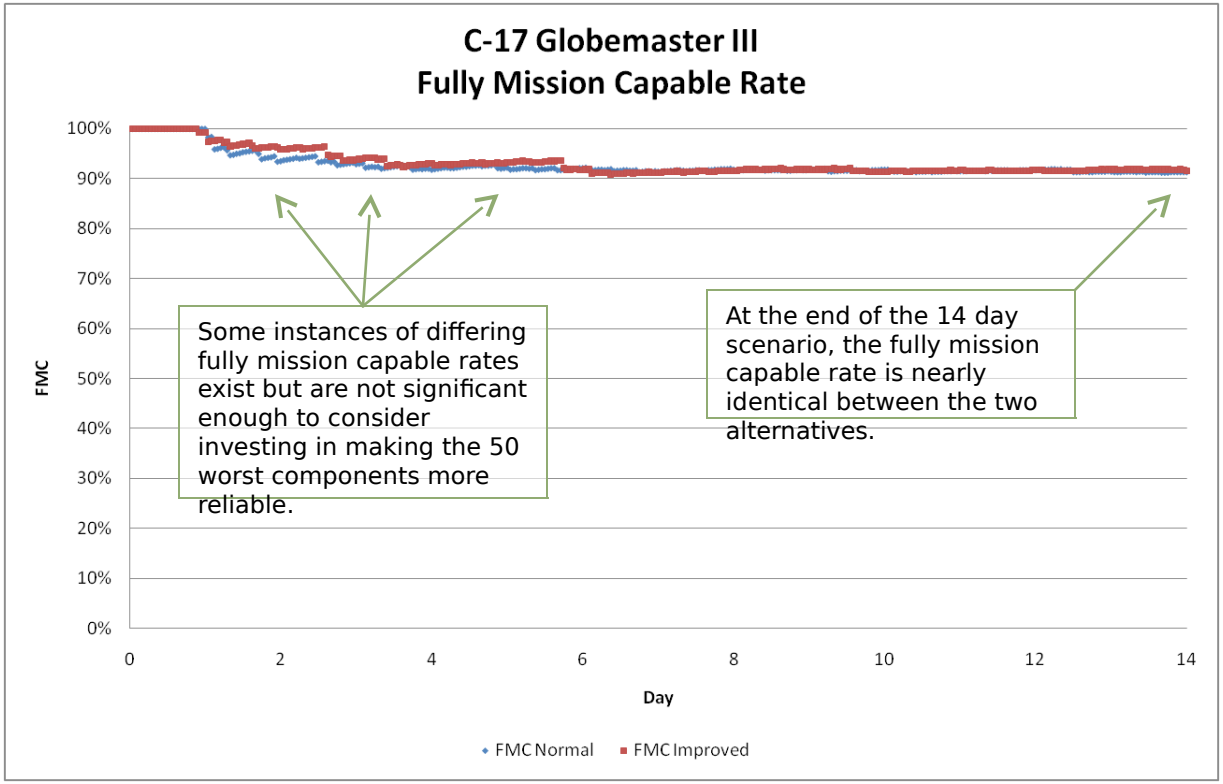
Q: Can I generate as many sorties per day using 8-hour manning shifts instead of 12-hour shifts?



A: No. Reducing available manning by using an 8-hour shift results in a 25% lower daily sortie generation rate than a 12-hour shift (4.5 sorties vs. 6 sorties).

Example Question and Answer 2

Q: How much will my fully mission capable rate improve if the reliability of the 50 worst components is upgraded by 100% (i.e. twice as reliable)?



A: The fully mission capable rate improves by 0.3% when improving the 50 least reliable components in the 14 day scenario.

Simulation Demonstration

- Weapon System: CV-22 Osprey
- Shift: Twelve hour

- Independent Variable Settings:

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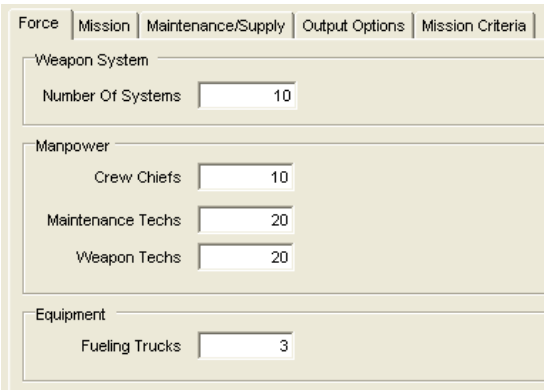

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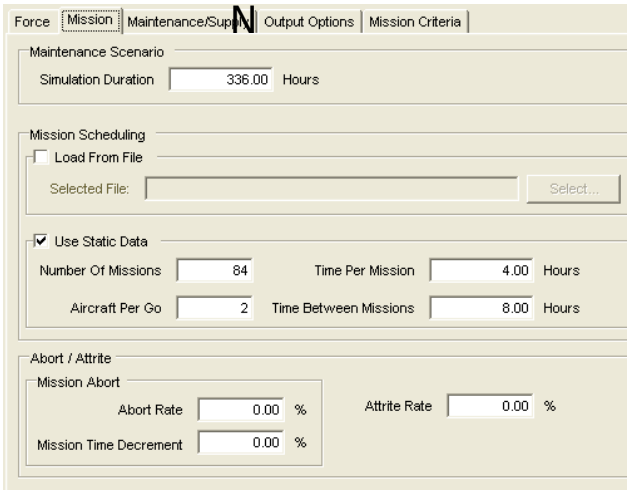

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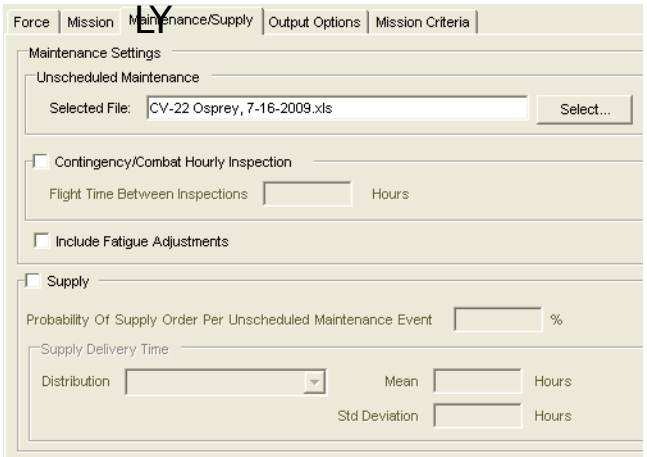
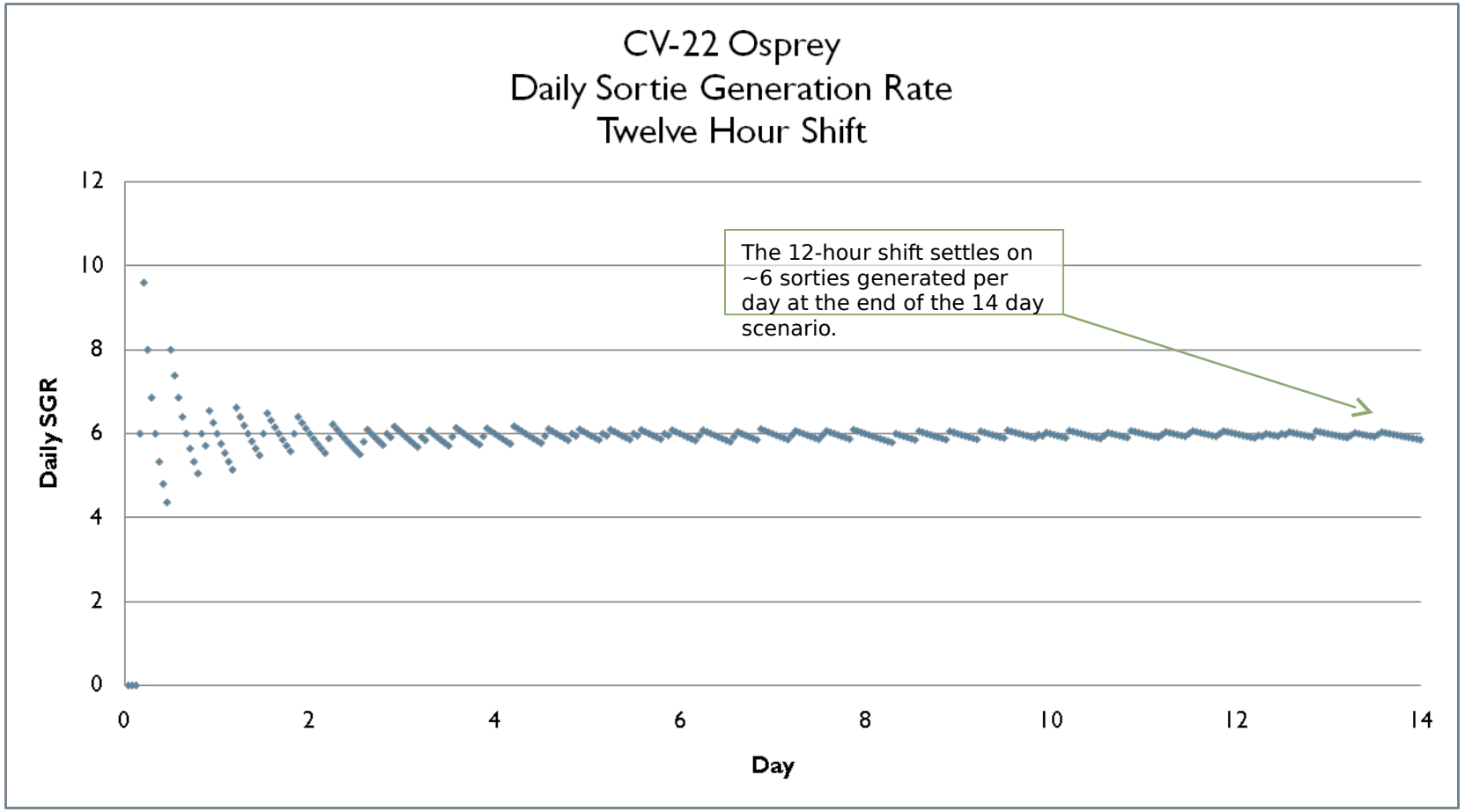


Simulation Demonstration

- Weapon System: CV-22 Osprey
- Shift: Twelve hour



Simulation Demonstration

- Weapon System: CV-22 Osprey
- Shift: Eight hour

- Independent Variable Settings:

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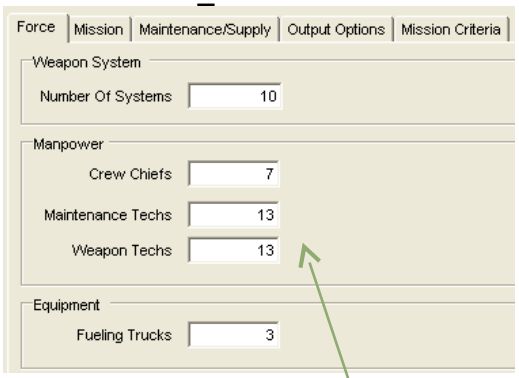

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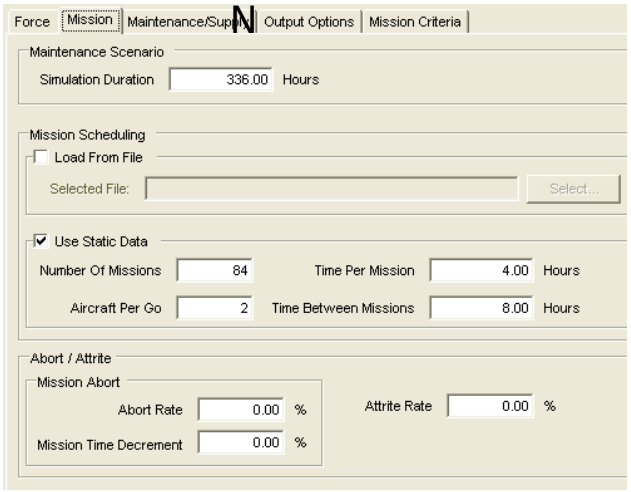
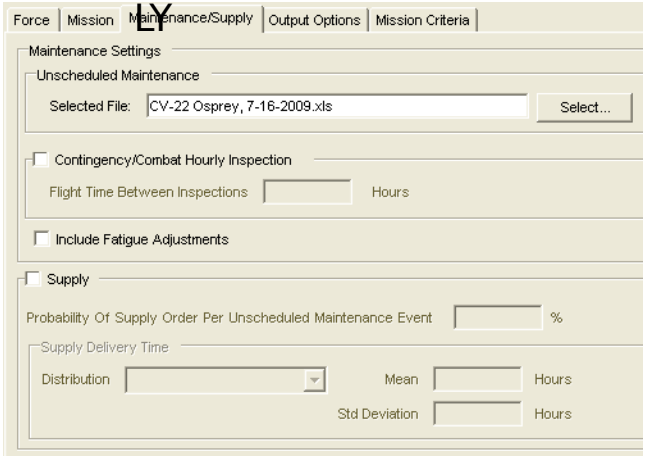


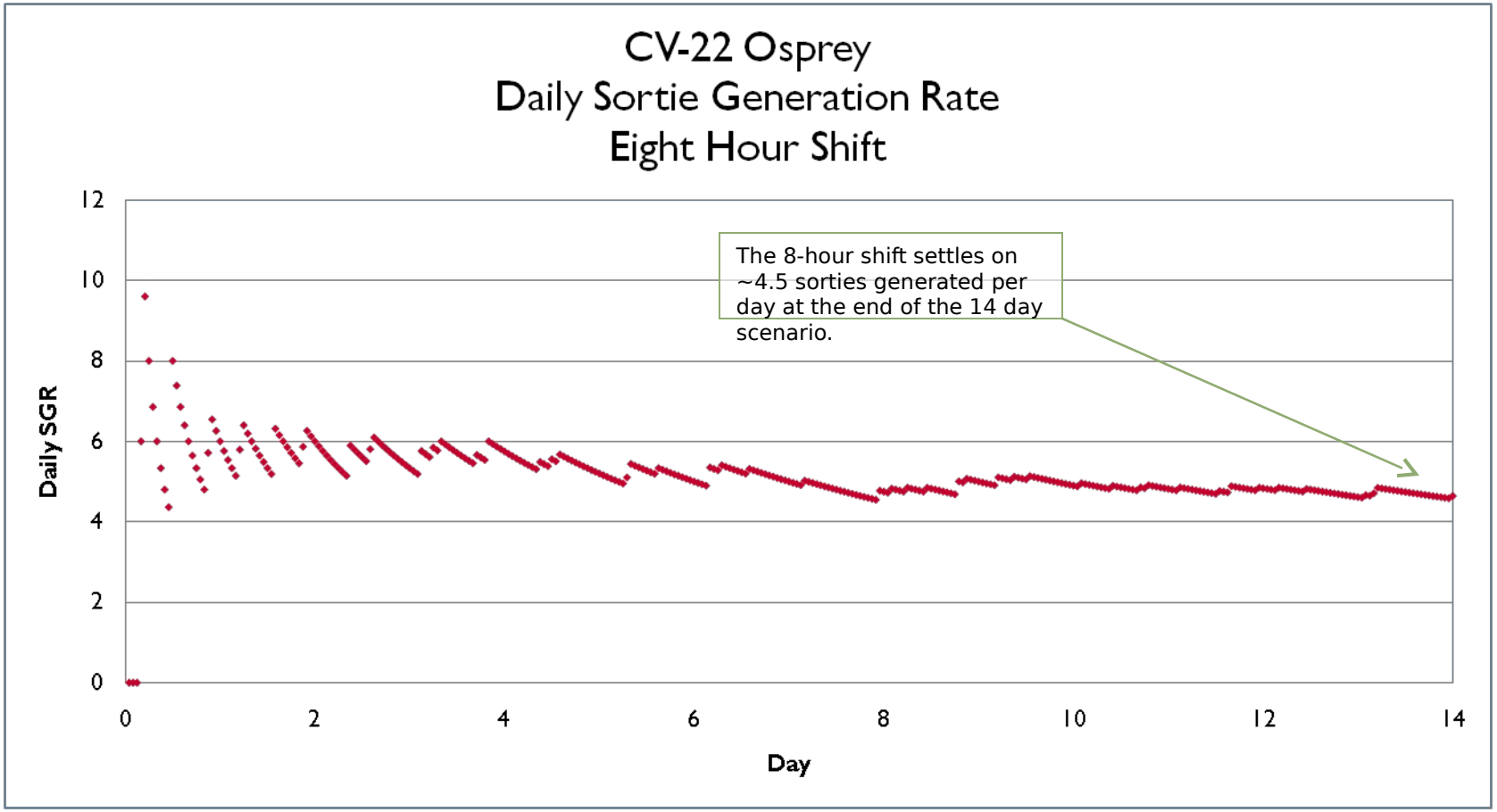
MAINTENANCE/SUPPLY



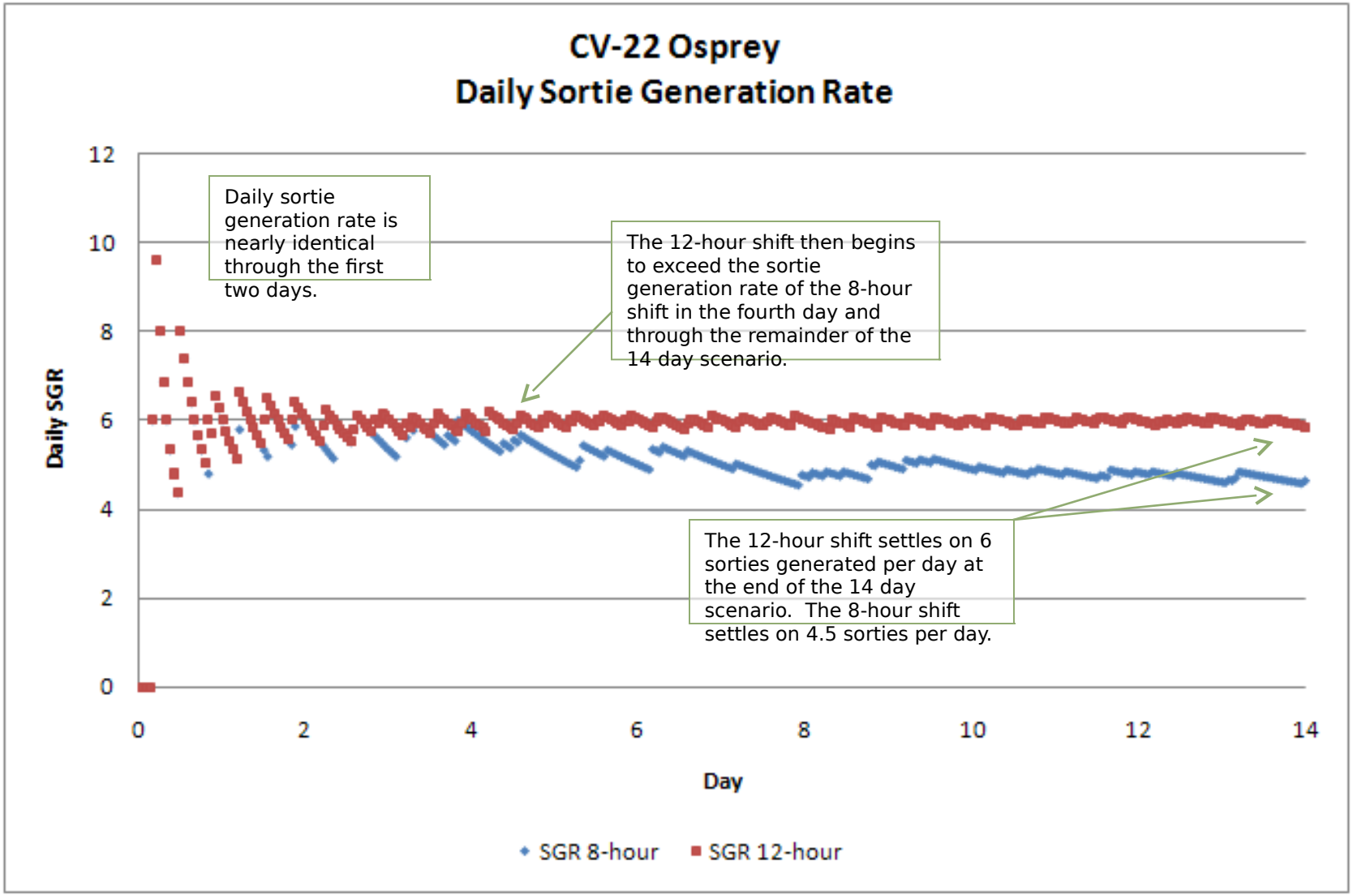
33% reduction in available manpower to support mission generation over a 12 hour shift.

Simulation Demonstration

- Weapon System: CV-22 Osprey
- Shift: Eight hour



Simulation Demonstration



Potential Future Enhancements of the AF HSI Mx Model

- Maintenance
  - Major preventive maintenance inspections (e.g. hourly post flight, preventive, home station checks).
- Personnel
  - Selection of available manpower by Air Force Specialty Code (AFSC)
  - Matching of malfunctioned component to the corresponding AFSC
  - Performance of repair times by AFSC
- Environment, Safety, and Occupational Health
  - Predicting the chances of an incident occurring predicated on past accident rates
- Work Shifts
  - An interface for prescribing exact manpower details by hour

Summary

- Many practical questions regarding weapon system readiness and capability can be easily answered using the simulation.
  - Offers a low-cost and low-risk capability for predicting AF performance.
- Results of the human performance simulation show the significance of the human's impact on AF capability and performance.
- By extension, HSI remains a critical discipline for the engineering and acquisition of AF weapon systems.